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(54) Ultra-wideband achromatic lens.

(57) An ultra-wide band achromatic lens which provides simultaneous multiband coverage from the visible to the very near infrared range of the energy spectrum. The lens (10) is made of three alternating elements 12, 14 and 16 of calcium fluoride or magnesium oxide in relative optical alignment. In a first embodiment, the elements are arranged in a Cooke triplet with a first positive (convergent) element 12 of calcium fluoride, a second negative (divergent) element 14 of magnesium oxide, and a third positive element 16 of calcium fluoride. In a second embodiment, a wide-angle triplet is provided with a first negative element 12 of magnesium oxide, a second positive element 14 of calcium fluoride, and a third element 16 of magnesium oxide.

In both embodiments, the invention provides an achromatic optical system which is simultaneously corrected for chromatic and other aberrations over the multiband wavelength range from the visible to the very near infrared portion of the energy spectrum, i.e., .5 microns to 5 microns.

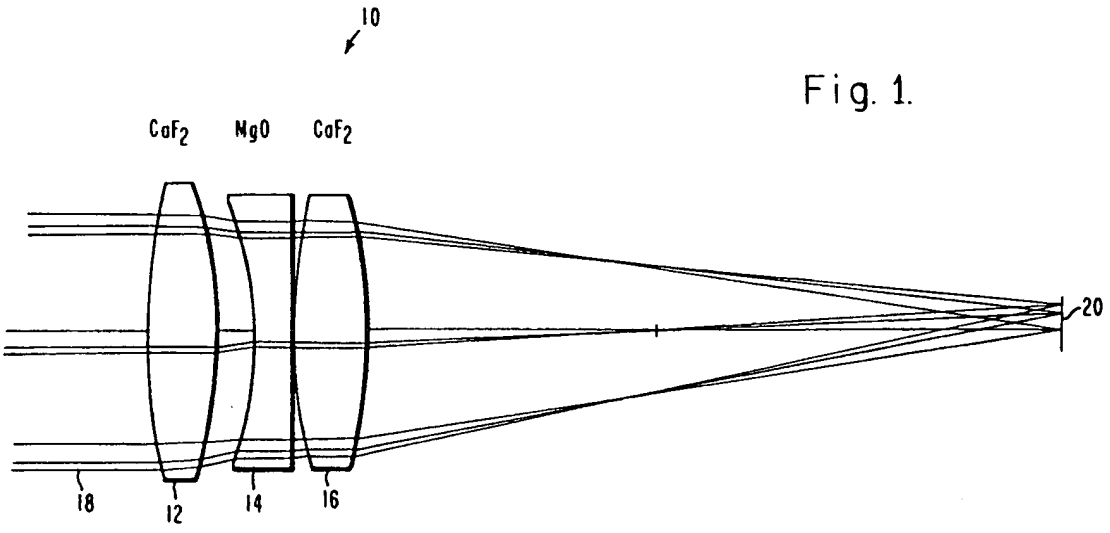

Fig. 1.

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In both embodiments, the invention provides an achromatic optical system which is simultaneously corrected for chromatic and other aberrations over the multiband wavelength range from the visible to the very near infrared portion of the energy spectrum, i.e., .5 microns to 5 microns.

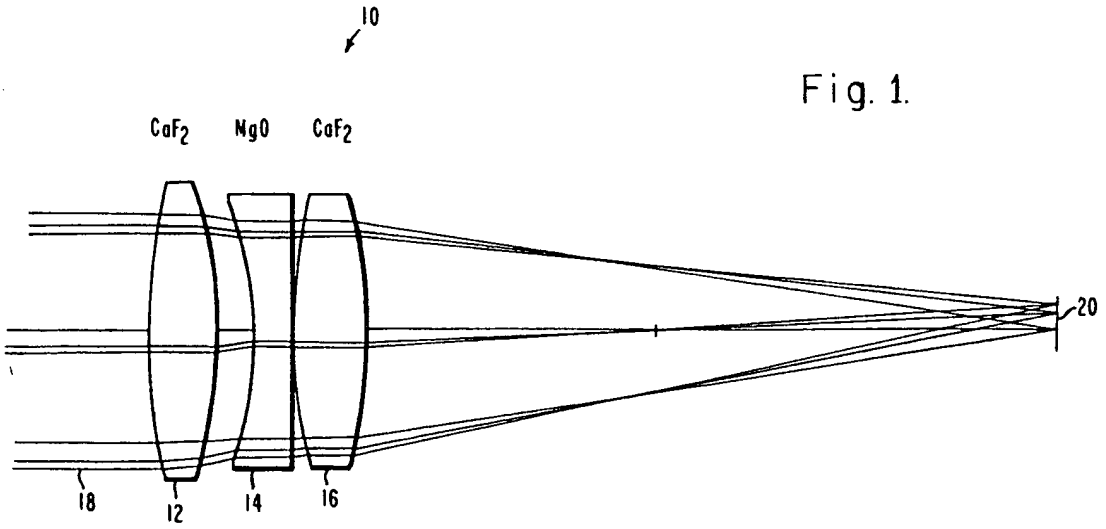

Fig. 1.

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ured as a Cooke triplet with the first and third elements 12 and 16 being convergent (positive) and the second element 14 being divergent (negative). In accordance with the present teachings, the first and third elements 12 and 16 are constructed of calcium fluoride and the second element 14 is constructed of magnesium oxide.

In the second embodiment, the lens 10 is configured as a wide-angle triplet with the first and third elements 12 and 14 being divergent (negative) and the second element 14 being convergent (positive). In accordance with the present teachings, the first and third elements 12 and 16 are of magnesium oxide construction and the second element 14 is of calcium fluoride construction.

In the best mode, each of the elements 12, 14 and 16 in each embodiment is of single crystal construction. As may be recognized by those skilled in the art, the embodiment of Fig. 1 is generally faster than that of Fig. 2 with a more narrow field-of-view (FOV). Accordingly, the embodiment of Fig. 2 is better suited for applications in which a wide FOV is desired over speed. (In this context, speed refers to the rate of convergence of optical energy passing through the lens. The faster the lens, the more quickly output energy converges on the target detector. Speed is typically expressed as the "f-number" of the lens which is the ratio of the focal length of the output beam to the diameter of the lens. The lower the f-number, the faster the lens.)

In both embodiments, the invention provides an achromatic optical system which is simultaneously corrected for chromatic and other aberrations over the multiband wavelength range from the visible to the very near infrared portion of the energy spectrum, i.e., .5 microns to 5 microns.

Each of the lenses described above are designed and constructed in a conventional manner. In practice, the lens is first designed using a computer optical design program such as Code v from Optical Research Associates of Pasadena, California or Accos V from Scientific Calculations, Inc. of Fishers, New York. The general shape of each element is input by specifying the radius of curvature of each surface, the material choice for that element and the thickness of the element. The airspaces between elements are also specified at this point. The system requirements are then input with respect to the desired f-number, the focal length, and image quality in terms of spot size by way of example. Next, the range of wavelengths is input over which the system is specified to provide good performance thereover. The variable parameters are specified. (These are typically based on mechanical constraints which are user defined and/or based on limitations of the materials chosen.) An optimization run is then performed, usually in several iterations, to obtain the required optical performance.

The program will then output:

1) an optical prescription, a list of each surface with
   a) the radius of curvature of each surface,
   b) the material following each surface, and
   c) the thickness of the surface and
2) performance in terms of image quality over the specified FOV (again, measured in terms of spot size).

Next, the program will perform a tolerance analysis, if required. A shop or fabrication diagram is then provided specifying the materials to be used, the shape and the tolerances of each, based on the program outputs.

Finally, the lens is manufactured in a conventional manner by a qualified optical manufacturer.

Thus, the present invention has been described herein with reference to a particular embodiment for a particular application. Those having ordinary skill in the art and access to the present teachings will recognize additional modifications applications and embodiments within the scope thereof. For example, the invention is not limited to the number of elements used in a lens. Any number of lenses may be used to satisfy the requirements of a particular application without departing from the scope of the present teachings. Further, the invention is not limited to a single crystal construction. Polycrystalline construction may be used as well.

It is therefore intended by the appended claims to cover any and all such applications, modifications and embodiments within the scope of the present invention.

Claims

1. An ultra-wide band achromatic lens comprising:

   a first element constructed of calcium fluoride;

   a second element, in optical alignment with said first element, constructed of magnesium oxide; and

   a third element, in optical alignment with said first and second elements, constructed of calcium fluoride.

2. The invention of Claim 1 wherein said first element is convergent.

3. The invention of Claim 2 wherein said second element is divergent.

4. The invention of Claim 3 wherein said third element is convergent.

5. The invention of Claim 1 wherein said first element is divergent.

6. The invention of Claim 5 wherein said second element is convergent.

7. The invention of Claim 6 wherein said third element is divergent.

8. An ultra-wide band achromatic lens comprising:
a first element constructed of magnesium oxide;
a second element, in optical alignment with said first element, constructed of calcium fluoride; and
a third element, in optical alignment with said first and second elements, constructed of magnesium oxide.

9. The invention of Claim 8 wherein said first element is convergent.

10. The invention of Claim 9 wherein said second element is divergent.

11. The invention of Claim 10 wherein said third element is convergent.

12. The invention of Claim 8 wherein said first element is divergent.

13. The invention of Claim 12 wherein said second element is convergent.

14. The invention of Claim 13 wherein said third element is divergent.

15. A missile apparatus with an ultra-wide band achromatic lens comprising:
a first convergent element constructed of calcium fluoride;
a second divergent element, in optical alignment with said first element, constructed of magnesium oxide; and
a third convergent element, in optical alignment with said first and second elements, constructed of calcium fluoride.

16. A missile apparatus with an ultra-wide band achromatic lens comprising:
a first convergent element constructed of magnesium oxide;
a second divergent element, in optical alignment with said first element, constructed of calcium fluoride;
and
a third convergent element, in optical alignment with said first and second elements, constructed of magnesium oxide.

Fig. 1.

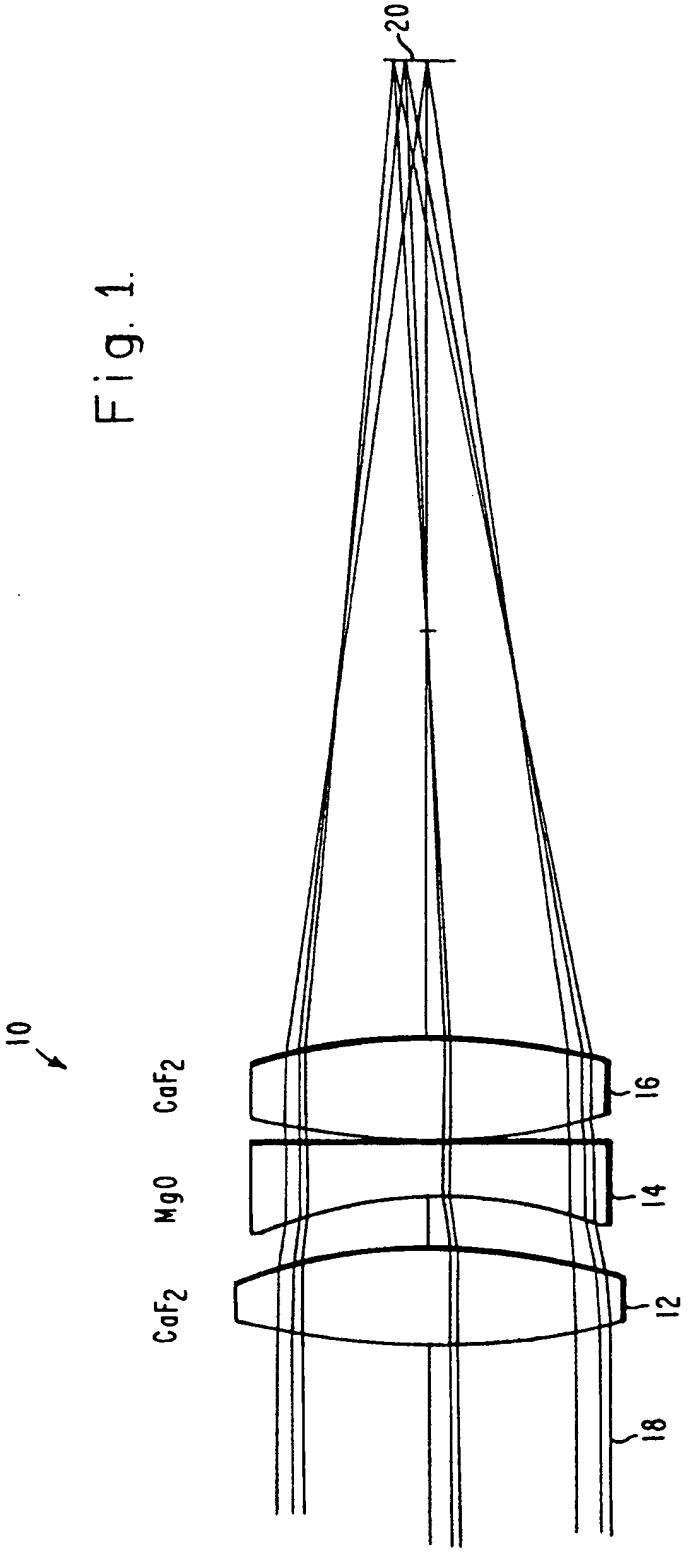
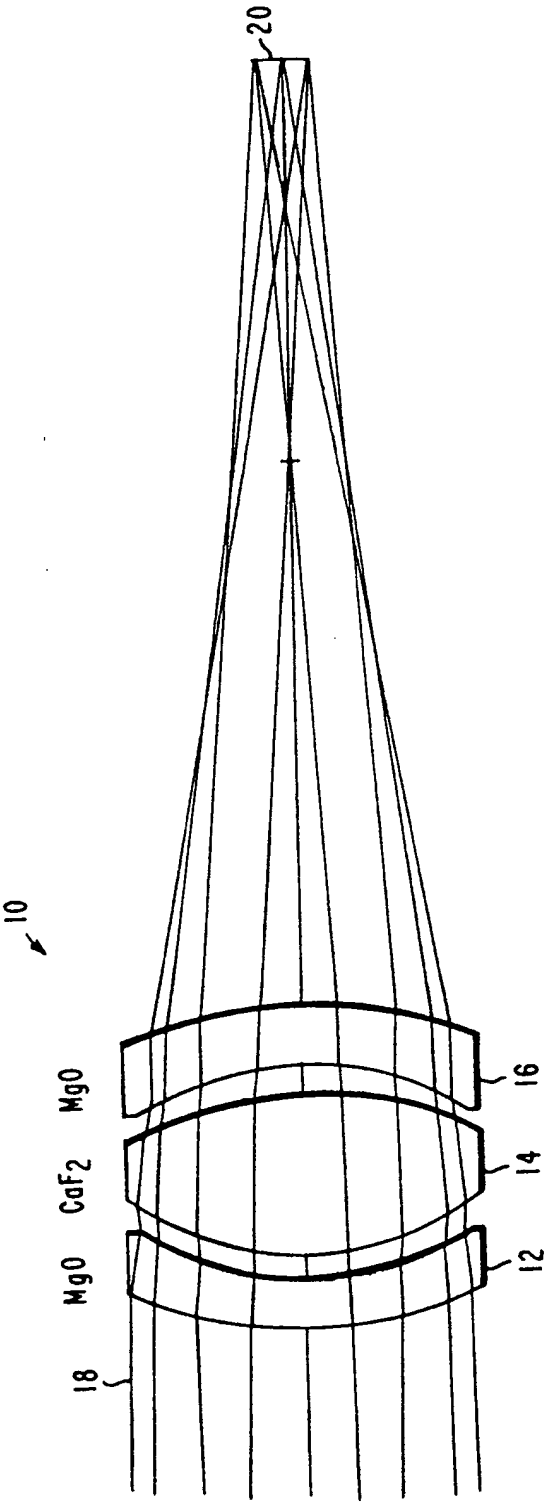


Fig. 2.



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EUROPEAN SEARCH REPORT

Application Number

EP 91 11 1692

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	OPTICAL ENGINEERING vol. 23, no. 2, March-April 1984, pages 187-192, Bellingham, Washington, US; M.W. MCDOWELL et al.: "Achromatization in the 3 to 5 Mum spectral region with visible light transmitting materials" * whole document *	1-3,8-10, 15,16	G 02 B 13/14 G 02 B 1/02
A	US-A-4 712 886 (MERCADO) * column 1, lines 21-43; figures 1,3 *	1,8	
A	OPTICAL ENGINEERING vol. 23, no. 2, March/April 1984, pages 111-116, Bellingham, Washington, US; T.H. JAMIESON: "Ultrawide waveband optics" * Introduction; figures 6-9 *	1,8	
A	DE-A-3 120 276 (UNITED STATES DEPARTMENT OF ENERGY) * page 5, paragraph 2; figure 1 *	5-7,12-14	
A	US-A-3 766 080 (SWINEHEART et al.) * figure 4; table 1 *	15,16	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

G 02 B 13/00
G 02 B 9/00
G 02 B 1/00

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
Berlin	23 October 91	VON MOERS F

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same catagory
A : technological background
O : non-written disclosure
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E : earlier patent document, but published on, or after the filing date
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